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*Indian Standard*

# METHODS FOR DETERMINATION OF CHARACTERISTICS OF FOCAL SPOTS IN DIAGNOSTIC X-RAY TUBE ASSEMBLIES FOR MEDICAL USE

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# Indian Standard

# METHODS FOR DETERMINATION OF CHARACTERISTICS OF FOCAL SPOTS IN DIAGNOSTIC X-RAY TUBE ASSEMBLIES FOR MEDICAL USE

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# Indian Standard

## METHODS FOR DETERMINATION OF CHARACTERISTICS OF FOCAL SPOTS IN DIAGNOSTIC X-RAY TUBE ASSEMBLIES FOR MEDICAL USE

## 0. FOREWORD

**0.1** This Indian Standard was adopted by the Indian Standards Institution on 26 August 1986, after the draft finalized by the Electromedical Equipment Sectional Committee had been approved by the Electrotechnical Division Council.

**0.2** While preparing this standard, assistance was derived from IEC Pub 336 ( 1982 ) 'Characteristics of focal spots in diagnostic X-ray tube assemblies for medical use', issued by the International Electrotechnical Commission ( IEC ).

**0.3** For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

## 1. SCOPE

**1.1** This standard deals with methods of determining characteristics of focal spots of diagnostic X-ray tube assemblies for medical use, operating at X-ray tube potential differences up to and including 200 kV.

**1.2** It is not intended that this standard be applied for the determination of the characteristics of focal spots of X-ray tube assemblies particularly designed for use in equipment for reconstructive tomography.

*Rules for rounding off numerical values ( *revised* ).

**1.3** Measuring methods and requirements for test arrangements to be applied for evaluating compliance with this standard are described together with the means of indicating compliance both of the specified characteristics of focal spots and the radiograms prepared in checking these characteristics.

## 2. TERMINOLOGY

**2.1 Accompanying Documents** — Documents provided with an electrical installation, electrical equipment or accessory and containing important information for the assembler, installer and user, particularly regarding safety.

**2.2 Actual Focal Spot** — Area on the surface of the target that intercepts the beam of accelerated particles.

**2.3 Anode** — In an X-ray tube, electrode to which electrons forming a beam are accelerated and which usually contains the target.

**2.4 Anode Speed** — In a rotating anode X-ray tube, angular velocity at which the anode rotates, usually expressed in revolutions per minute.

**2.5 Blooming Value** — As a characteristic of the effective focal spot of an X-ray tube, ratio of two star pattern resolution limits obtained under specific measuring conditions.

**2.6 Effective Focal Spot** — Perpendicular projection of the actual focal spot on the reference plane.

NOTE — The shortened term 'focal spot' refers to the 'effective focal spot.'

**2.7 Focal Spot Pinhole Radiogram** — Radiogram obtained by means of a pinhole camera, showing the shape and orientation of an effective focal spot and the spatial distribution of radiant intensity of the radiation emitted across the effective focal spot.

**2.8 Focal Spot Slit Radiogram** — Radiogram obtained by means of a slit camera, showing the distribution of radiant intensity in the direction normal to the length of the slit, of the radiation emitted across an effective focal spot.

**2.9 Focal Spot Star Radiogram** — Radiogram obtained by means of a star pattern camera, for the determination of the star pattern resolution limit in one or more directions across an effective focal spot.

**2.10 Focal Track** — In a rotating anode X-ray tube, part of the anode which is struck by the beam of electrons during rotation of the anode.

**2.11 Intensifying Screen** — Layer of material used in direct radiography to convert the incident X-radiation or gamma radiation into radiation more suitable for the radiation-sensitive emulsion of the radiographic film.

**2.12 Irradiation Time** — Duration of an irradiation determined according to specific methods, usually the time a rate of radiation quantity exceeds a specified level.

**2.13 Loading Factor** — Factor influencing by its value the X-ray tube load, for example, X-ray tube current, loading time, equivalent anode input power, X-ray tube voltage and percentage ripple.

**2.14 Loading Time** — Time, determined according to a specified method, during which the anode input power is applied to the X-ray tube.

**2.15 Modulation Transfer Function** — As a characteristic of the focal spot of an X-ray tube, absolute value of the Fourier transform of the one-dimensional distribution of radiant intensity emitted across the effective focal spot.

**2.16 Nominal Anode Input Power** — Highest constant anode input power that can be applied for a single X-ray tube load in a specific loading time.

**2.17 Nominal Focal Spot Value** — Dimensionless numerical value having a specific relation to the dimensions of the effective focal spot of an X-ray tube, measured under specific conditions.

**2.18 Nominal X-ray Tube Voltage** — Highest permitted X-ray tube voltage for specific operation conditions.

**2.19 Non-Screen Film** — In direct radiography, radiographic film for use without an intensifying screen.

**2.20 Normal Use** — Operation, including stand-by state, according to the instructions for use or for the obvious intended purpose.

**2.21 Pinhole Camera** — Assembly of equipment used to obtain a focal spot pinhole radiogram on radiographic film.

**2.22 Radiographic Film** — Sheet or roll material consisting of a transparent carrier covered with radiation-sensitive emulsion on one or usually both sides and designed for use in direct radiography.

**2.23 Radiographic Rating** — For the operation of an X-ray tube, specified combination of conditions and loading factors under which the specified limits of loadability of the X-ray tube are attained.

**2.24 Reconstructive Tomography** — Tomography in which the information obtained from the object is recorded and allows the reconstruction of images of layers in the object by corresponding treatment or processing.

**2.25 Reference Axis** — For a radiation source, line parallel to the reference direction through the centre of the radiation source.

**2.26 Reference Direction** — For a radiation source, specified direction to which characteristics such as target angle, radiation field and specifications with respect to the imaging quality of the radiation source are referenced.

**2.27 Reference Plane** — For an effective focal spot, plane perpendicular to the reference direction containing the point at which the reference axis intersects with the actual focal spot.

**2.28 Rotating Anode X-ray Tube** — X-ray tube in which the anode rotates.

**2.29 Slit Camera** — Assembly of equipment used to obtain a focal spot slit radiogram on radiographic film.

**2.30 Specific** — When used in combination with parameters or conditions referring to a particular value or standardized arrangement, usually to those required in an IEC standard.

**2.31 Specified** — When used as an adjective in combination with parameters or conditions referring to a value or arrangement to be chosen for the purpose under consideration and indicated, usually in the accompanying documents.

**2.32 Star Pattern Camera** — Assembly of equipment used to obtain a focal spot star radiogram on radiographic film.

**2.33 Star Pattern Resolution Limit** — As a characteristic of the focal spot of an X-ray tube, lowest spatial frequency which cannot be imaged under specific measuring conditions.

**2.34 Target** — Part of an X-ray tube or a particle accelerator onto which is directed a beam of accelerated particles to produce ionizing radiation or other particles.

**2.35 X-ray Tube** — Evacuated vessel for the production of X-radiation by the bombardment of a target, usually contained in an anode, with electrons accelerated from a cathode by an electric field.

**2.36 X-ray Tube Assembly** — X-ray tube housing with an X-ray tube installed.

**2.37 X-ray Tube Current** — Electric current through the anode of an X-ray tube. The X-ray tube current is expressed by its mean value in milliamperes ( mA ).

**2.38 X-ray Tube Housing** — Container for an X-ray tube providing protection against electric shock and against X-radiation and having a radiation aperture. The X-ray tube housing may optionally contain additional components.

**2.39 X-ray Tube Load** — Electrical energy supplied to an X-ray tube expressed by a combination of values of loading factors.

**2.40 X-ray Tube Voltage** — Potential difference applied to an X-ray tube between the cathode and the anode. The X-ray tube voltage is expressed by its peak value in kilovolts ( kV ).

## 3. PRINCIPLE OF MEASUREMENT

**3.1** Today, the X-ray tube technology as well as the systematic investigation of imaging procedures has developed significantly. The earlier method for the determination of the dimensions of a focal spot based upon a focal spot pinhole radiogram was very difficult if nominal focal spot values were smaller than 0·3 because the results are affected by factors, such as transmission through the shielding of the diaphragm and the need for repeated irradiations of the radiographic film due to tube loading considerations. Therefore, a new method, using a pair of focal spot slit radiograms has heen developed which will be applied over the entire range of usual nominal focal spot values. It avoids former uncertainties in determining the dimensions of focal spots and gives valuable results even in cases of distorted focal spots. Furthermore, it provides basic data in the form of pair of focal spot slit radiograms allowing determination of the imaging properties of the focal spots in the form of a pair of one-dimensional, modulation transfer functions.

**3.2** Thus, not only the method for the determination of the dimensions of focal spots but also that for the determination of the modulation transfer function will be based exclusively upon the use of the pair of focal spot slit radiograms for all normal focal spot values.

**3.3** In addition, further standard methods are described for establishing focal spot characteristic. These are in common use and will continue to have their place for use by manufacturers ( focal spot pinhole radiograms ) and in the field ( focal spot star radiograms ).

**3.4** Maintaining the multiplier 0·7 for nominal focal spot values of 0·3 and greater is justifiable due to the fact that these focal spots are almost exclusively designed for very high loads which cause the distribution in radiant intensity over the length to exhibit a pronounced peak with relatively shallow shoulders. This results in larger linear dimensions for the length of the focal spot compared to width even though the modulation transfer functions for both width and length may be approximately equal.

**3.5** Focal spots in the range below 0·3 are normally designed for magnification techniques with a more rectangular distribution of the radiant intensity over both width and length. Here the modulation transfer functions are comparatively equal thereby indicating the same dimensions for width and length. Additionally, in the absence of earlier standards, there is no sound reason to perpetuate the factor of 0·7 for the new range.

**3.6** The production of focal spot star radiograms has been standardized because of their usefulness in making a simple assessment of the imaging properties of a system under field conditions by establishing the star pattern resolution limit under those conditions ( assuming the focal spot has such a characteristic ).

## 4. INFORMATION

**4.1** Index of information regarding specific aspects characterizing the focal spot and method of determining such characteristics is given in Table 1.

**TABLE 1 METHODS FOR EVALUATION OF SPECIFIC ASPECTS CHARACTERIZING THE FOCAL SPOT**

| Equipment Used to Obtain Information | Clause Ref | Information Obtained<br>Charateristics of Focal Spot | Clause Ref | Evaluation of Compliance with |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| Pair of focal spot slit radiograms ( *see* Note 1 ) | 5 | Dimensions | 8 | Specified nominal focal spot value |
| | | Imaging | 9 | Specified pair of one - dimensional modulation transfer |
| Focal spot pinhole radiogram | 6 | Orientation<br>Radiant instensity distribution<br>Symmetry | | |
| Focal spot star radiogram ( *see* Note 2 ) | 7 | Star pattern resolution limit | 10 | |
| | | Blooming value | 11 | |
| | | Modification of focal spot properties over the life time | | |

NOTE 1 — A method for the determination of the rms value of the line spread function as a further characteristic of the focal spot is under consideration.

NOTE 2 — The distribution of radiant intensity over a focal spot does not always provide a point where the modulation transfer function will reach the spatial frequency axis; in this case, the method by means of a focal spot star radiogram is not applicable.

## 5. FOCAL SPOT SLIT RADIOGRAMS

**5.0** Focal spot slit radiograms are used for the determination of focal spot dimensions according to **8** and determination of the modulation transfer function according to **9**. A method of production of focal spot slit radiograms is given below.

### 5.1 Test Equipment

**5.1.1** *Slit Camera* — Focal spot slit radiograms shall be oblained by means of a slit camera containing a slit diaphragm of the dimensions given in Fig. 1.

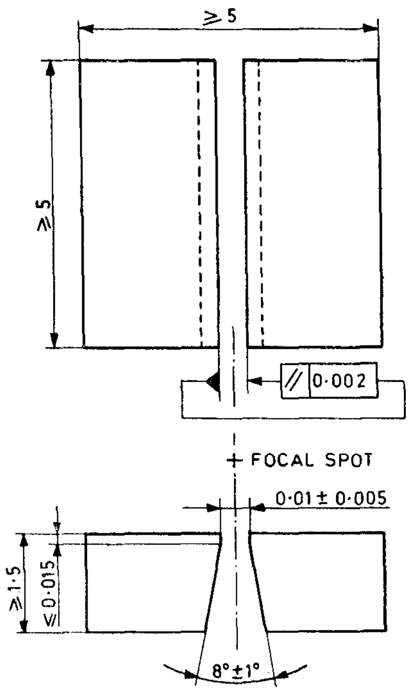



FIG. 1 ESSENTIAL DIMENSIONS OF SLIT DIAPHRAGM

**5.1.2** The slit diaphragm shall be made from any one of the following:

a) tungsten,

b) tantalum,

c) alloy of gold and 10 percent platinum,

d) alloy of tungsten and 10 percent rhenium, or

e) alloy of platinum and 10 percent iridium.

**5.1.3** *Radiographic Film* — Focal spot slit radiograms shall be made on a fine grain radiographic film for use without intensifying screens, for example, dental radiographic film.

**5.2 Test Arrangement**

**5.2.1** *Alignment of Slit Camera* — The reference axis shall pass through the centre of the incident face of the slit diaphragm and shall form an angle with the axis of symmetry of the slit diaphragm smaller than or equal to $10^{-3}$ radian ( *see* Fig. 2 ). Appendix A gives information regarding alignment to the reference axis.

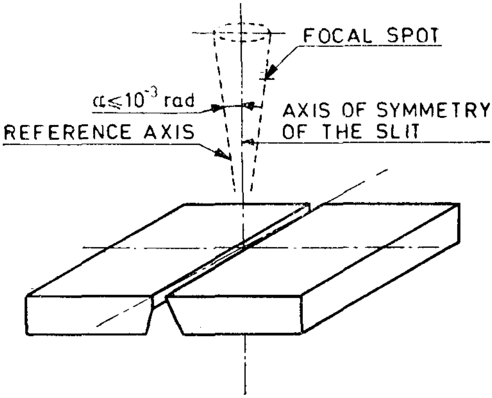



FIG. 2 ALIGNMENT OF SLIT CAMERA

**5.2.2** *Position of Slit Camera* — The incident face of the slit diaphragm shall be placed at a distance from the focal spot so that the variation of the magnification over the extension of the actual focal spot does not exceed $\pm 5$ percent in the reference direction ( *see* Fig. 3 ), according to the following forumlae:

$$\frac{n}{m} = E; \quad \frac{n}{m+k} \geqslant 0{\cdot}95\,E; \quad \frac{n}{m-p} \leqslant 1{\cdot}05\,E$$

where

$E$ = magnification,

$k$ = distance from the reference plane to the edge of the actual focal spot distal from the diaphragm,

$m$ = distance from the reference plane to the incident face of the diaphragm,

$n$ = distance from the radiographic film to the incident face of the diaphragm, and

$p$ = distance from the reference plane to the edge of the actual focal spot near to the diaphragm.

In no case shall these distances be less than 100 mm.

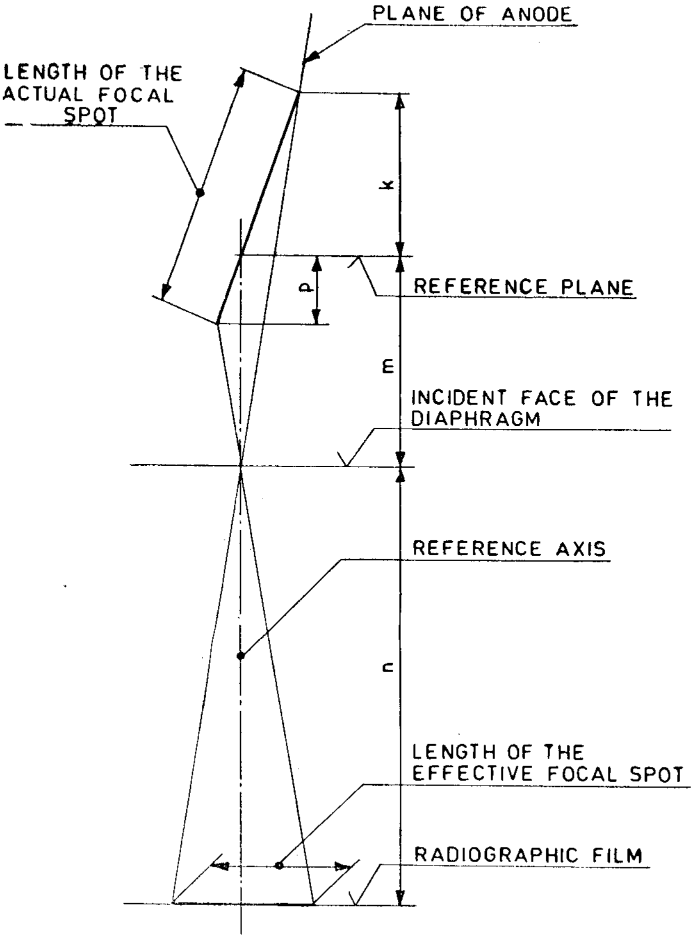



FIG. 3 REFERENCE DIMENSIONS AND PLANES

5.2.3 *Orientation of Slit Diaphragm*

**5.2.3.1** For the production of a pair of focal spot slit radiograms, slit diaphragm shall be orientated so that the length of the slit is normal within $\pm 0{\cdot}09$ radian ( $\pm 5°$ ) to each of two directions of evaluation.

**5.2.3.2** For measurements over the length of the focal spot, the direction of evaluation shall be parallel to the longitudinal axis of the X-ray tube assembly or to a specified longitudinal axis.

**5.2.3.3** For measurements over the width of the focal spot, the direction of evaluation shall be general, normal to the direction of evaluation according to **5.2.3.2**.

If the projection of the effective focal spot in the reference direction is distorted, the direction of evaluation over the width may be chosen normal to the pronounced orientation of the regions of highest radiant intensity, usually the direction over the focal spot showing the smallest width ( *see* Fig. 4 ).

For visualization of orientation and the distribution of radiant intensity, *see* focal spot pinhole radiograms in **6**.

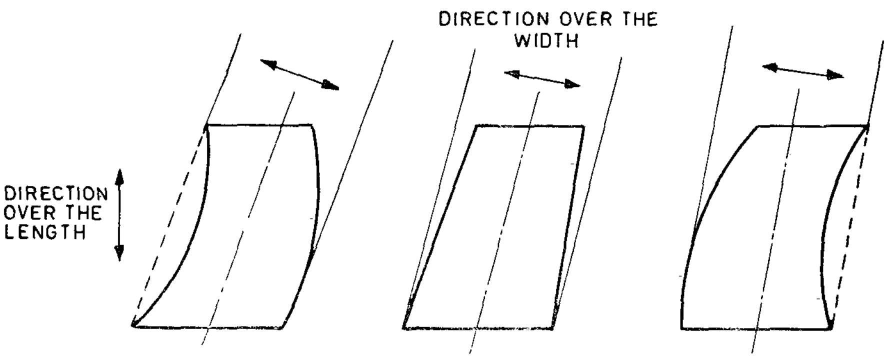



FIG. 4 DIRECTIONS OF EVALUATION OVER DISTORTED FOCAL SPOT

**5.2.3.4** If the X-ray tube assembly does not have an identifiable longitudinal axis, a longitudinal axis shall be specified together with the focal spot characteristics.

## 5.3 Position of Radiographic Film

**5.3.1** The radiographic film shall be placed normal to the reference at a distance from the incident face of the slit diaphragm determined from the appropriate magnification according to Table 2.

**TABLE 2 MAGNIFICATION FOR FOCAL SPOT SLIT RADIOGRAMS**

( *Clause* 5.3.1 )

| NOMINAL FOCAL SPOT VALUE ( *see* **8.2** ), $f$ | MAGNIFICATION ( *see* Fig. 3 ), $E = \frac{n}{m}$ |
|---|---|
| (1) | (2) |
| $f \leqslant 0.4$ | $E \geqslant 3$ |
| $0.5 \leqslant f \leqslant 1.0$ | $E \geqslant 2$ |
| $1.1 \leqslant f$ | $E \geqslant 1$ |

## 5.4 Operating Conditions

**5.4.1** *X-ray Tube Assembly* — The X-ray tube shall be installed in an X-ray tube housing of the type for which it is specified for normal use or it shall be placed under equivalent mounting and operating conditions as far as these can influence the results of the test.

**5.4.2** *Loading Factors*

**5.4.2.1** Focal spot radiogram(s) shall be obtained with constant loading factors according to Table 3.

**TABLE 3 LOADING FACTORS**

( *Clauses* 5.4.2.1 *and* 5.4.2.2 )

| NOMINAL X-RAY TUBE VOLTAGE, $U$ | LOADING FACTOR | |
|---|---|---|
| | Required X-ray tube voltage | Required X-ray tube current |
| (1) | (2) | (3) |
| kV | | |
| $U \leqslant 75$ | Nominal X-ray tube voltage | 50 percent of X-ray tube current which corresponds to the nominal anode inupt power specified for the focal spot |
| $75 < U \leqslant 150$ | 75 kV | |
| $150 < U \leqslant 200$ | 50% of nominal X-ray tube voltage | |

NOTE 1 — The X-ray tube current determining the nominal adode input power may be applicable for loading times up to 0·1 s. The value of 50 percent is applicable loading times according to the radiographic ratings for longer loading times necessary for the required blackening of the radiographic film.

NOTE 2 — For rotating anode X-ray tubes, the anode shall be rotated at the highest anode speed specified in the applicable radiographic ratings.

5.4.2.2 *Special loading factors* — If the loading factors according to Table 3 do not fall within the radiographic ratings for the X-ray tube concerned or if they otherwise do not cover the typical special applications of specified normal use of the X-ray tube, appropriate loading factors shall be chosen. In this case, the loading factors under which the focal spot radiogram(s) were obtained, shall be stated together with the charactersitic(s).

NOTE 1 — The loading factors according to Table 3 are reasonable for the usual diagnostic X-ray tubes with application over a wide range in X-ray tube voltages and X-ray tube load. For X-ray tubes specified for special applrications which are applied over small ranges of X-ray tube voltages and X-ray tub loads, the loading factors for the test shall correspond to those specific applications. In particular cases, it will be appropriate, as information to the user, to give the characteristics of a focal spot for several conditions of loading.

5.4.3 *Special Arrangements* — If, for the purpose of producing suitable focal spot radiograms, special arrangements were made for adjustment and alignment of slit camera and X-ray tube assembly or if special electrical or loading conditions prevailed, details shall be stated together with the characteristic(s) in the statement of compliance.

## 5.5 Production of Focal Spot Slit Radiograms

**5.5.1** The direction of evaluation over the width of the focal spot according to **5.2.3.3** shall be determined.

**5.5.2** A pair of focal spot slit radiograms shall be produced as given in **5.1** to **5.4**.

**5.5.2.1** The radiographic film shall be exposed so that after full development, a local diffuse density between 1·0 and 1·4 is obtained in areas of highest blackening found in the central third or half of the slit image width at the mid point of its length. The blackening of the film due to fog and base shall not exceed a diffuse density of 0·2.

## 5.6 Statement of Compliance

**5.6.1** If compliance with this standard for a pair of focal spot slit radiograms is to be stated, this shall be done as follows:

Focal spot slit radiogrm with magnification used and determined in accordance with **8.3.5**, together with the following, as appropriate:

a) Loading factors ( *see* **5.4.2.2** ),

b) Special arrangements ( *see* **5.4.3** ), and

c) Description of the longitudinal axis of the X-ray tube assembly ( *see* **5.2.3.4** ).

## 6. FOCAL SPOT PINHOLE RADIOGRAMS

**6.1** Focal spot pinhole radiograms are used for showing orientation and distribution of radiant intensity over the effective focal spot. A method of indicating compliance with this standard of a focal spot pinhole radiogram is included.

### 6.2 Test Equipment

**6.2.1** *Pinhole Camera* — Focal spot pinhole radiograms shall be obtained by means of a pinhole camera containing a pinhole diaphragm with a pinhole having the dimensions given in Table 4 for the corresponding nominal focal spot value. The essential dimensions of a pinhole diaphragm are given in Fig. 5.

**TABLE 4 DIMENESIONS OF THE PINHOLE**

| Nominal Focal Spot Value | Dimensions (mm) | |
|---|---|---|
| | Diameter, *P* | Height, *H* |
| (1) | (2) | (3) |
| $f < 1{\cdot}0$ | $0{\cdot}030 \pm 0{\cdot}005$ | $0{\cdot}075 \pm 0{\cdot}010$ |
| $1{\cdot}1 \leqslant f$ | $0{\cdot}100 \pm 0{\cdot}005$ | $0{\cdot}500 \pm 0{\cdot}010$ |

**6.2.1.1** The pinhole diaphragm shall be made from any one of the following:

i) tungsten,

ii) tantalum,

iii) alloy of gold and 10 percent platinum,

iv) alloy of tungsten and 10 percent rhenium, or

v) alloy of platinum and 10 percent iridium.

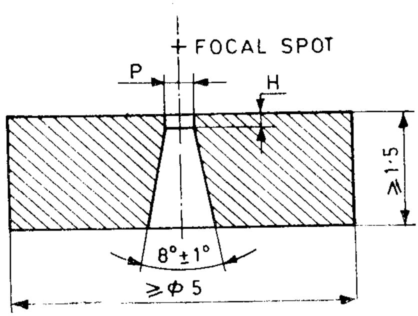



FIG. 5 ESSENTIAL DIMENSIONS OF A PINHOLE DIAPHRAGM

**6.2.2** *Radiographic Film* — Focal spot pinhole radiograms shall be made on a fine grain radiographic film for use without intensifying screens, for example, dental radiographic film.

## 6.3 Test Arrangement

**6.3.1** *Alignment of the Pinhole Camera* — The reference axis shall form an angle with the axis of the pinhole smaller than or equal to $10^{-3}$ radian ( *see* Fig. 6 and Appendix A ).

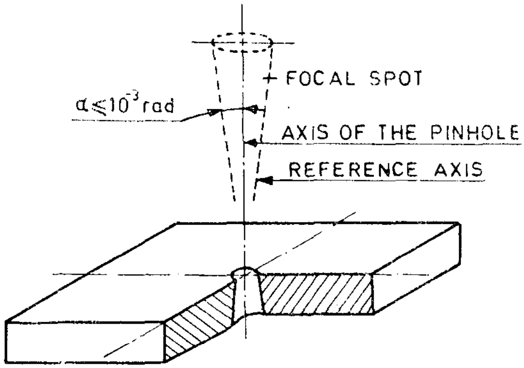



FIG. 6 ALIGNMENT OF PINHOLE CAMERA

**6.3.2** *Position of Pinhole Camera* — The incident face of the pinhole diaphragm shall be placed at a distance from the focal spot so that the variation of the magnification over the extension of the actual focal spot does not exceed $\pm 5$ percent in the reference direction ( *see* **5.2** and Fig. 3 ). In no case shall this distance be less than 100 mm.

**6.3.3** *Position of Radiographic Film* — The radiographic film shall be placed normal to the reference direction at a distance from the incident face of the pinhole diaphragm determined from the applicable magnification according to Table 5.

**TABLE 5 MAGNIFICATION FOR FOCAL SPOT PINHOLE RADIOGRAMS**

| NOMINAL FOCAL SPOT VALUE ( *see* **8.2** ), $f$ | MAGNIFICATION ( *see* Fig. 3 ), $E = \frac{n}{m}$ |
|---|---|
| (1) | (2) |
| $f \leqslant 1.0$ | $E \geqslant 2$ |
| $1.1 \leqslant f$ | $E \geqslant 1$ |

**6.4 Operating Conditions** — The focal spot pinhole radiograms shall be obtained under the operating conditions described in **5.4**.

**6.5 Production of Focal Spot Pinhole Radiograms** — The radiographic film shall be exposed so that after full development, a local diffuse density between 1·0 and 1·4 is obtained in areas of highest blackening. The blackening of the film due to fog and base shall not exceed a diffuse density of 0·2.

**6.6 Statement of Compliance** — If compliance with this standard for a focal spot pinhole radiogram is to be stated, this shall be done as follows:

Focal spot pinhole radiogram with magnification used according to **8.3.5**, together with the following, as appropriate:

a) Loading factors ( *see* **5.4.2.2** ),

b) Special arrangements ( *see* **5.4.3** ), and

c) Description of the longitudinal axis of the X-ray tube assembly ( *see* **5.2.3.4** ).

## 7. FOCAL SPOT STAR RADIOGRAMS

**7.1** The method of production of focal spot star radiograms used for determination of star pattern resolution limit and blooming value of focal spots described in **10** is given below.

A method of indicating compliance with this standard of a focal spot star radiogram is included.

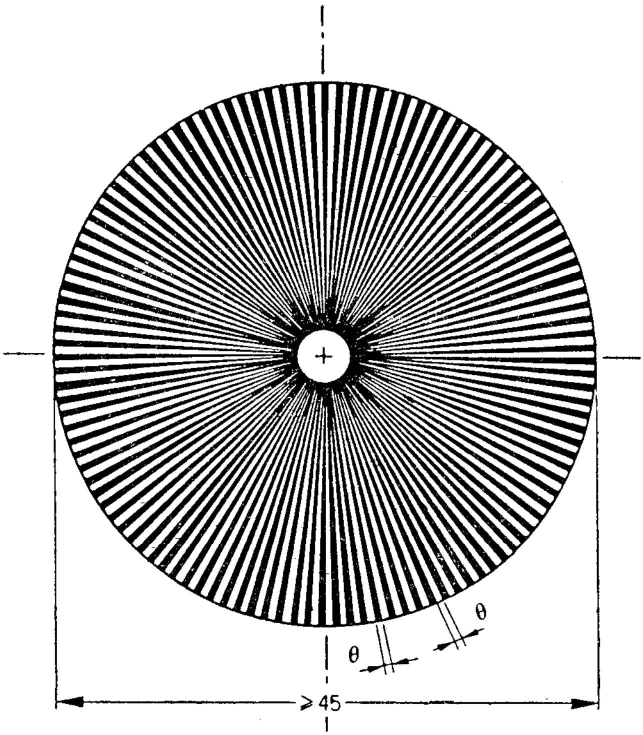
### 7.2 Test Equipment

**7.2.1** *Star Pattern Camera* — Focal spot star radiograms shall be obtained by means of a star pattern camera containing a test pattern which consists of an array of alternating high and low absorbing wedges. The high absorbing wedges shall be made of lead or an equivalent material and shall have a thickness of 0·03 to 0·05 mm,

All wedges shall have a vertex angle $\theta$ equal to or less than 0·035 radian ( approximately 2° ).

The active area of the test pattern shall cover $2\pi$ radians and shall have a diameter of at least 45 mm.

The essential dimensions of the test pattern and its basic structure shall be as shown in Fig. 7.




All dimensions in millimetres.

FIG. 7 ESSENTIAL DIMENSIONS OF TEST PATTERN

**7.2 Radiographic Film** — Focal spot star radiograms shall be made on any fine grain radiographic film for use without intensifying screens, for example, non-screen film.

**7.3 Test Arrangement**

**7.3.1** *Alignment of Star Pattern Camera* — The reference axis shall form an angle with the axis of the test pattern smaller than or equal to $10^{-3}$ radian ( *see* Fig. 8 and Appendix A ).

**7.3.2** *Position of Star Pattern Camera* — The incident face of the test pattern shall be placed normal to the reference direction at a distance from the focal spot allowing a magnification $M'$ of a value such that the dimensions $Z_W$ and $Z_L$, measured according to **10.3** will be more than or,

where this is not practicable, as near as possible to one-third of the diameter of the image of the test pattern but not less than 25 mm ( *see also* **7.3.3** ).

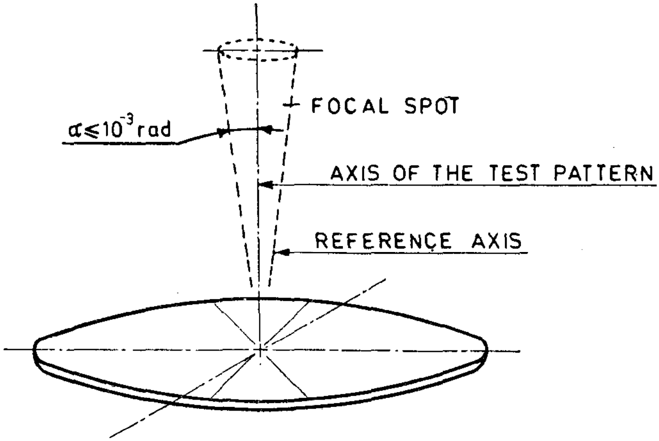



FIG. 8 ALIGNMENT OF STAR PATTERN CAMERA

**7.3.3** *Position of Radiographic Film* – The radiographic film shall be placed normal to the reference direction at a distance from the incident face of the test pattern which results in a magnification $M'$ as determined from the expected star pattern resolution limit $R$, according to the formula:

$$M' = R\,Z\theta$$

where

$M'$ = magnification to be used,

$R$ = expected star pattern resolution limit in line pairs per millimetre,

$Z$ = dimension on the radiogram of the appropriate outmost distorted zone in millimetres, and

$\theta$ = vertex angle of the absorbing wedges in radians.

## 7.4 Operating Conditions

**7.4.1** The focal spot star radiogram shall be obtained under the operating conditions described in **5.4**.

**7.5 Production of Focal Spot Star Radiograms**

**7.5.1** The radiographic film shall be exposed so that after full development, a local diffuse density between 1·0 and 1·4 is obtained for the regions of the low absorbing wedges which show the highest blackening. The blackening of the film due to fog and base shall not exceed a diffuse density of 0·2.

**7.6 Statement of Compliance** — If compliance with this standard for a focal spot star radiogram is to be stated, this shall be done together with the magnification determined according to **10.4.1** as follows:

Focal spot star radiogram with magnification ...... ( *see* Note ).

NOTE — The magnification shall be stated as a numerical value.

## 8. DETERMINATION OF FOCAL SPOT DIMENSIONS

**8.1** The method of determination of focal spot dimensions on the basis of a pair of focal spot slit radiograms is given below. Criteria for compliance with this standard and the method of indicating nominal focal spot values in compliance with this standard are included.

**8.2 Specified Nominal Focal Spot Values**

**8.2.1** *Nominal Values* — To the focal spots of each type of X-ray tube assembly, nominal focal spot values shall be assigned, the values being:

i) 0·1 to 0·2 in steps of 0·05,

ii) 0·3 to 2·0 in steps of 0.1, and

iii) 2·2 and upwards in steps of 0·2.

**8.2.2** *Actual Values* — The nominal focal spot value shall be related to the dimensions in the two directions of evaluation over the focal spot so that the values for the width and the length of the focal spot determined according to **8.3.5** are between the values given in Table 6.

**8.3 Measurement and Determination**

**8.3.1** *Measurement* — The dimensions over the focal spot shall be determined from a pair of focal spot slit radiograms.

**8.3.2** *Measuring Arrangement* — The focal spot slit radiograms obtained according to **3** shall be backlighted at approximately 3 000 lx. They shall be examined by eye through a magnifying lens with a built-in graticule with divisions of 0·1 mm and a magnification 10.

**8.3.3** *Measurement of Linear Dimensions* — The extent of blackening shall be measured over each focal spot slit radiogram perpendicular to the length of the slit image at half of its length.

**TABLE 6 PERMISSIBLE VALUES OF FOCAL SPOT DIMENSIONS FOR NOMINAL FOCAL SPOT VALUES**

( *Clauses* 8.2.2 *and* 8.4.1 )

| Nominal Focal Spot Value | Permissible Values of Focal Spot Dimensions mm | |
|---|---|---|
| | Width | Length |
| (1) | (2) | (3) |
| 0·1 | 0·10 to 0·15 | 0·10 to 0·15 |
| 0·15 | 0·15 to 0·23 | 0·15 to 0·23 |
| 0·2 | 0·20 to 0·30 | 0·20 to 0·30 |
| 0·3 | 0·30 to 0·45 | 0·45 to 0·65 |
| 0·4 | 0·40 to 0·60 | 0·60 to 0·85 |
| 0·5 | 0·50 to 0·75 | 0·70 to 1·1 |
| 0·6 | 0·6 to 0·9 | 0·9 to 1·3 |
| 0·7 | 0·7 to 1·1 | 1·0 to 1·5 |
| 0·8 | 0·8 to 1·2 | 1·1 to 1·6 |
| 0·9 | 0·9 to 1·3 | 1·3 to 1·8 |
| 1·0 | 1·0 to 1·4 | 1·4 to 2·0 |
| 1·1 | 1·1 to 1·5 | 1·6 to 2·2 |
| 1·2 | 1·2 to 1·7 | 1·7 to 2·4 |
| 1·3 | 1·3 to 1·8 | 1·9 to 2·6 |
| 1·4 | 1·4 to 1·9 | 2·0 to 2·8 |
| 1·5 | 1·5 to 2·0 | 2·1 to 3·0 |
| 1·6 | 1·6 to 2·1 | 2·3 to 3·1 |
| 1·7 | 1·7 to 2·2 | 2.4 to 3·2 |
| 1·8 | 1·8 to 2·3 | 2·6 to 3·3 |
| 1·9 | 1·9 to 2·4 | 2·7 to 3·5 |
| 2·0 | 2·0 to 2·6 | 2·9 to 3·7 |
| 2·2 | 2·2 to 2·9 | 3·1 to 4·0 |
| 2·4 | 2·4 to 3·1 | 3·4 to 4·4 |
| 2·6 | 2·6 to 3·4 | 3·7 to 4·8 |
| 2·8 | 2·8 to 3·6 | 4·0 to 5·2 |
| 3·0 | 3·0 to 3·9 | 4·3 to 5·6 |

NOTE — For nominal focal spot values from 0·3 to 3·0 inclusive, the permissible values in this table include the factor 0·7 ( *see* **3** ).

**8.3.4** *Accuracy of Measurement* — The indicated tolerances comprise the uncertainties of the measuring method.

**8.3.5** *Determination of Width and Length of Focal Spot* — The magnification $E$ used shall be determined with an accuracy within $\pm 3$ percent.

Each linear dimension measured according to **8.3.3** shall be divided by the magnification $E$ used.

**8.4 Evaluation and Statement of Compliance**

**8.4.1** *Evaluatian of Compliance* — The values for the width and the length of the focal spot determined according to **8.3** in millimetres shall not exceed the permissible values for the nominal focal spot value given in Table 6.

**8.4.2** *Statement of Compliance* — If the compliance with this standard for one or more nominal focal spot value(s) is to be stated, this shall be done as single number(s) without any units, for example:

Nominal focal spot value 0·6 determined from focal spot slit radiograms. It shall be stated together with the following, as appropriate:

a) Loading factors ( *see* **5.4.2.2** ),

b) Special arrangements ( *see* **5.4.3** ), and

c) Description of the longitudinal axis of the X-ray tube assembly ( *see* **5.2.3.4** ).

## 9. MODULATION TRANSFER FUNCTION

**9.1** The determination of one-dimensional modulation transfer function of the geometry of the focal spot of an X-ray tube assembly on the basis of a pair of focal spot slit radiogoms is given below.

Criteria for compliance with this standard and a method of indicating modulation transfer functions in compliance with this standard are included.

**9.2 Specified Modulation Transfer Functions**

**9.2.1** A pair of one-dimensional modulation transfer functions of the geometry of each focal spot shall be specified for each type of X-ray tube assembly.

Compliance with this standard of the modulation transfer functions determined for an individual X-ray tube assembly shall be evaluated according to **9.7.1**.

**9.3 Measuring Equipment and Measuring Arrangement**

**9.3.1** The focal spot slit radiograms shall be scanned by means of a microdensitometer. The slit of the microdensitometer shall have a width $b$, referred to the focal spot slit radiogram not exceeding the width of the slit diaphragm used for the production of the radiograms.

The length of the slit of microdensitometer shall be limited so that it can be aligned to the direction of diaphragm slit projected on the radiogram in such a way that effective width $b_{eff}$, of the microdensitometer slit normal to the direction of the projected diaphragm slit will be smaller than twice the width, $b$, of the microdensitometer slit, as shown in Fig. 9.

The scanning direction shall be aligned normal to the direction of the diaphragm slit to within $\pm 1°$.

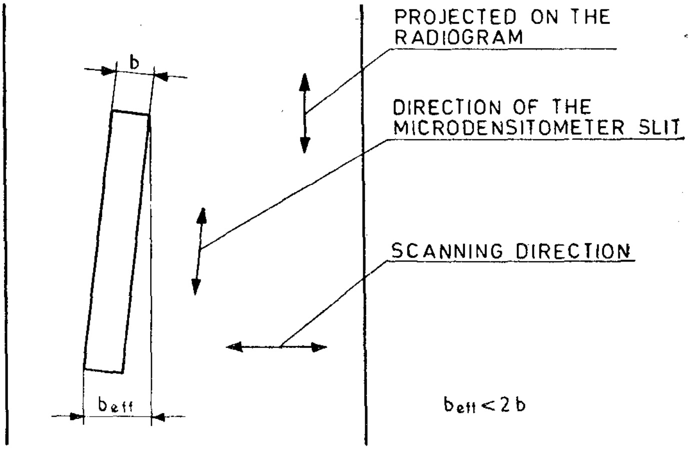



FIG. 9 ALIGNMENT OF SLIT OF THE MICRODENSITOMETER

## 9.4 Measurement

**9.4.1** *Measurement of Density Distribution* — The density over each focal spot slit radiogram obtained according to **5** shall be scanned normal to its longitudinal direction at half of its length.

The total range scanned shall be at least four times the range of the main lobe shown in Fig. 10.

The results of this measurement shall be presented as a curve showing density over the width of the radiogram.

The mesh of measuring points shall be chosen so fine that a further refinement of the mesh would not result in a significant change of the density curve.

**9.5 Corrections to be Applied** — The values of density above base and fog shall be transformed into a curve showing linear distribution over width of radiogram of the radiant intensity, by means of a sensitometric curve showing the relation between radiant intensity and density.

The sensitometric curve shall be established using an identical radiographic film processed under the same conditions as that used for the focal spot slit radiogram.

To limit input data for the calculation procedure of modulation transfer functions, the flanks of the curve of linear distribution of radiant intensity shall be reduced by linear extrapolation of the values at 15 percent and 5 percent of the maximum intensity as shown in Fig. 10.

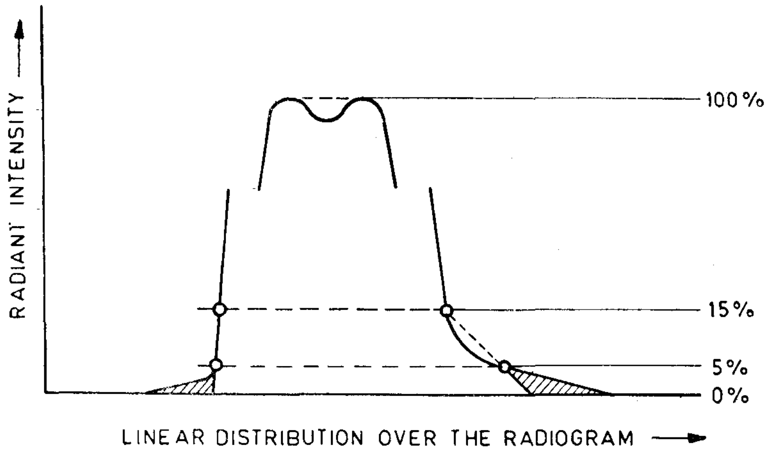



FIG. 10 LIMITATION OF INPUT DATA

## 9.6 Calculation of Modulation Transfer Function

**9.6.1** *Calculation for Theoretical Magnifications Approaching Infinity* — The one-dimensional modulation transfer function of the geometry of a focal spot shall be calculated by means of the Fourier transform.

The input values for carrying out the Fourier transform shall be the values of the linear distribution of radiant intensity over the focal spot slit radiogram, the abscissae in Fig. 10, divided by the magnification used according to **8.3.5** for the production of the focal spot slit radiogram and the corresponding values of radiant intensity, the ordinates in Fig. 10.

The mesh of ordinates along the axis of abscissae shall be chosen so fine that the extent and the structures of the linear distribution of radiant intensity over the focal spot will be taken into account and a further refinement of the mesh would not result in a significant change of the calculated modulation transfer function.

**9.6.2** *Calculation for Standard Magnification* — The values of spatial frequency obtained according to **9.4.1** shall be transformed according to the formula:

$$f_s = f_1 \frac{M_s}{M_s - 1}$$

where

$f_s$ = spatial frequency for standard magnification given in Table 7,

$f_1$ = spatial frequency obtained according to **9.6.1**, and

$M_s$ = standard magnification.

**TABLE 7 STANDARD MAGINFICATION FOR MODULATION TRANSFER FUNCTIONS**

( *Clauses* 9.5.2, 9.6.1 *and* 9.6.3 )

| Nominal Focal Spot Value $f$ | Standard Magnification $M_s$ |
|---|---|
| (1) | (2) |
| $f < 0.6$ | 2 |
| $0.6 \leqslant f$ | 1.3 |

**9.6.3** *Calculation for Finite Magnification* — For application of modulation transfer function under practical radiological conditions, the values obtained according to **9.5.2** or those given according to **9.6** are transformed according to the formula:

$$f_p = f_s \frac{M_s - 1}{M_s} \cdot \frac{M_p}{M_p - 1}$$

where

$f_p$ = spatial frequency for desired magnification,

$f_s$ = spatial frequency for standard magnification,

$M_s$ = standard magnification, and

$M_p$ = desired magnification.

**9.7 Presentation of Modulation Transfer Function**

**9.7.1** The modulation transfer function shall be given as a curve showing the amount of the Fourier transform for the standard magnification in Table 7 as a function of spatial frequency in line pairs per millimetre in a linear scale for both axes of co-ordinates so that for the spatial frequency zero, the amount of the Fourier transform is 100 percent.

**9.7.2** The modulation transfer function shall extend at least to the spatial frequency at which the amount of Fourier transform falls to 10 percent but beyond this not further than to the spatial frequency at which it reaches a first minimum or reaches the spatial frequency axis.

NOTE — Generally, the modulation transfer function beyond the first minimum is of little importance for practical applications.

**9.7.3** The pair of one-dimensional modulation transfer functions of the geometry of the width and length of one focal spot shall be presented in one diagram, together with the nominal focal spot value according to **8.4.2** and the standard magnification according to Table 7.

**9.8 Evaluation and Statement of Compliance**

**9.8.1** *Evaluation of Compliance of Modulation Transfer Function* — Each one-dimensional modulation transfer function of the geometry of an individual focal spot at any spatial frequency shall coincide with, or be higher than the specified modulation transfer function of the X-ray tube assembly according to **9.2.**

**9.8.2** *Statement of Compliance* — If the compliance with this standard of a pair of modulation transfer functions is to be stated, this shall be done, for example, as follows:

Modulation transfer function for a nominal focal spot value of 0·6 and magnification of 1·3.

It shall be stated together with the following, as appropriate:

a) Loading factors ( *see* **5.4.2.2** ),

b) Special arrangements ( *see* **5.4.3** ), and

c) Description of the longitudinal axis of the X-ray tube assembly ( *see* **5.2.3.4** ).

## 10. STAR PATTERN RESOLUTION LIMIT

**10.1** The results of this method are useful to detect changes of the characteristics of a particular focal spot depending upon varying conditions of X-ray tube load ( *see* **11** ) or after periods of use.

The method described in **10.3** and **10.4** does not give exact results if the modulation transfer function does not contain a clearly defined minimum, as for example, in cases where the radiant intensity has an approximately Gaussian distribution over the focal spot.

**10.2 Specified Star Pattern Resolution Limit** — If a type related star pattern resolution limit for the standard magnification given in Table 8 is established for a focal spot of an X-ray tube assembly, compliance with this standard of the star pattern resoultion limit for an individual X-ray tube assembly shall be evaluated according to **10.5**.

**TABLE 8 STANDARD MAGNIFICATION FOR STAR PATTERN RESOLUTION LIMIT**

( *Clauses* 10.2, 10.4.2 *and* 10.4.4 )

| NOMINAL FOCAL SPOT VALUE | STANDARD MAGNIFICATION |
|---|---|
| $f$ | $M_S$ |
| (1) | (2) |
| $f < 0{\cdot}6$ | 2 |
| $0{\cdot}6 \leqslant f$ | 1·3 |

**10.3 Measurement** — In focal spot star radiograms obtained according to **7**, the dimensions $Z_W$ and $Z_L$ of outermost distorted zone shall be measured in two direction of evaluation ( *see* **5.2.3.2**, **5.2.3.3** and Fig. 11 ).

**10.4 Determination of Star Pattern Resolution Limit**

**10.4.1** *Determination of Magnification* — The magnification, $M'$, used for production of the focal spot star radiogram shall be determined with an accuracy within $\pm 3$ percent.

**10.4.2** *Star Pattern Resolution Limit for Standard Magnification* — The star pattern resolution limits, $R_{WS}$ and $R_{LS}$, for standard magnification given in Table 8 shall be determined from the formulae:

$$R_{WS} = \frac{M' - 1}{Z_W\,\theta} \quad \frac{M_S}{M_S - 1}$$

$$R_{LS} = \frac{M' - 1}{Z_L\,\theta} \quad \frac{M_S}{M_S - 1}$$

where

| | | |
|---|---|---|
| $R_{Ws}$ and $R_{Ls}$ | = | values for two directions of evaluation in line pairs per millimetre, |
| $M'$ | = | magnification according to **10.4.1**, |
| $M_s$ | = | standard magnification, |
| $Z_W$ | = | mean diameter of outermost distorted zone measured in the direction parallel to be longitudinal axis of the X-ray tube assembly in millimetres, |
| $Z_L$ | = | mean diameter of outermost distorted zone measured in the direction normal to the longitudinal axis of the X-ray tube assembly in millimetres, and |
| $\theta$ | = | vertex angle of absorbing wedges in radians. |

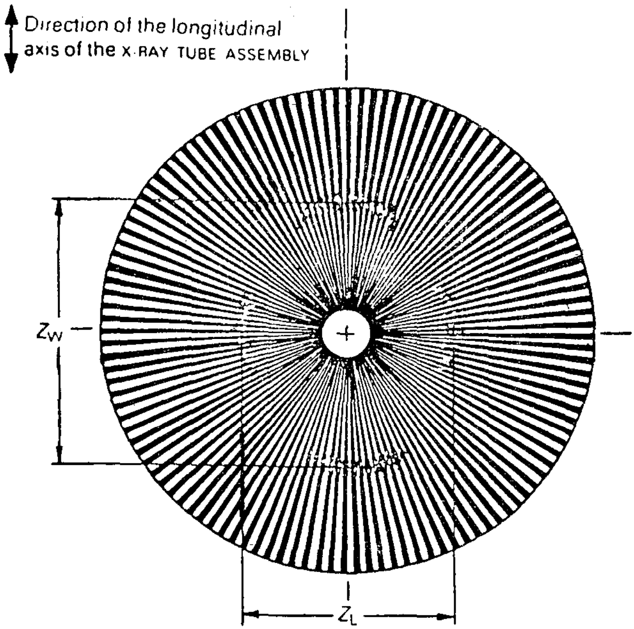



FIG. 11 IMAGE OF THE TEST PATTERN

**10.4.3** *Star Pattern Resolution Limit for Finite Magnification* — For the application of star pattern resolution limit under practical radiological conditions, the values $R_{Ws}$ and $R_{Ls}$ obtained according to **10.4.2** or those specified according to **10.2** can be transformed according to the formulae:

$$R_{Wp} = R_{Ws} \frac{M_s - 1}{M_s} \cdot \frac{M_p}{M_p - 1}$$

$$R_{Lp} = R_{Ls} \frac{M_s - 1}{M_s} \cdot \frac{M_p}{M_p - 1}$$

where

$R_{Wp}$ and $R_{Lp}$ = values for desired magnification,

$R_{Ws}$ and $R_{Ls}$ = values obtained according to **10.4.2** or specified according to **10.2**,

$M_s$ = standard magnification, and

$M_p$ = desired magnification.

**10.4.4** *Presentation of Star Pattern Resolution Limit* — The star pattern resolution limit shall be given for the standard magnification given in Table 8.

**10.5 Evaluation and Statement of Compliance**

**10.5.1** *Evaluation of Compliance* — If for a focal spot of an X-ray tube assembly, the star pattern resolution limit is specified, each value determined according to **10.4.2** shall be equal to, or greater than the specified value.

**10.5.2** *Statement of Compliance* — If the compliance with this standard for a specified star pattern resolution limit is to be stated, this shall be indicated as follows:

Star pattern resolution limit .... line per millimetere at standard magnification......... ( *see* Note ).

NOTE — The resolution limit shall be stated as a numerical value and the value of standard magnification shall be according to Table 7.

## 11. BLOOMING VALUE

**11.1** The subsequent clauses deal with determination of blooming value of a focal spot showing the dependence of size of the focal spot upon the X-ray tube load.

**11.2 Specified Blooming Value**

**11.2.1** If a type related blooming value is established for a focal spot of a type of X-ray tube assembly, compliance with this standard of the blooming value for an individual X-ray tube assembly shall be evaluated according to **11.4.1** based upon values established according to **11.3.**

**11.3 Determination of Blooming Value**

**11.3.1** The blooming value shall be determined using pairs of star pattern resolution limits established according to **10,** based upon focal spot star radiograms obtained with constant loading factors according to Table 3 and Table 9 under the same operating conditions.

**TABLE 9 LOADING FACTORS FOR DETEMINATION OF BLOOMING VALUE**

| Nominal X-ray Tube Voltage, $U$ kV | Loading Factors | |
|---|---|---|
| | Required X-ray Tube Voltage | Required X-ray Tube Current |
| (1) | (2) | (3) |
| $U \leqslant 75$ | Nominal X-ray tube voltage | Highest X-ray tube current given in radiographic rating for a loading time of 0·1 s at the required X-ray tube voltage |
| $75 < U \leqslant 150$ | 75 kV | |
| $150 < U \leqslant 200$ | 50% of the nominal X-ray tube voltage | |

The blooming value, $B$, results from the following formula:

$$B = \frac{R_{50}}{R_{100}}$$

where

$R_{50}$ = star pattern resolution limit under operating conditions according to Table 3, and

$R_{100}$ = corresponding value under operating conditions according to Table 9.

**11.4 Evaluation of Compliance**

**11.4.1** If for a focal spot of an X-ray tube assembly, the blooming value is specified, each value determined according to **11.3** shall be smaller than or equal to the specified value.

# APPENDIX A

( *Clauses* 5.2.1, 6.3.1 *and* 7.3.1 )

## ALIGNMENT TO REFERENCE AXIS

**A-1.** The values of the characteristics of a focal spot obtained by measurement and determination according to this standard are dependent upon various factors which are difficult to avoid or to compensate for, without very expensive test instrumentation and test procedures which can be expected in purpose equipped test laboartories only.

**A-2.** One of these factors is the geometric alignment of slit diaphragm or pinhole diaphragm to the centre of the effective focal spot projected in the reference direction to the effective plane of the slit or pinhole diaphragm.

**A-3.** Unless otherwise specified, it is assumed for the puspose of this standard that the target plane and the position of the target are sufficiently adjusted and aligned to, and that the reference axis can be identified with respect to reference points at the outside of the X-ray tube assembly and, consequently, the slit or pinhole diaphragm can be adjusted properly without verification of the actual position of the focal spot.

For double focus X-ray tube on different focal tracks, this alignment refers to the mid-position between the two effective focal spots. In this case correction factors shall be applied.

# INTERNATIONAL SYSTEM OF UNITS ( SI UNITS )

## Base Units

| *Quantity* | *Unit* | *Symbol* |
|---|---|---|
| Length | metre | m |
| Mass | kilogram | kg |
| Time | second | s |
| Electric current | ampere | A |
| Thermodynamic temperature | kelvin | K |
| Luminous intensity | candela | cd |
| Amount of substance | mole | mol |

## Supplementary Units

| *Quantity* | *Unit* | *Symbol* |
|---|---|---|
| Plane angle | radian | rad |
| Solid angle | steradian | sr |

## Derived Units

| *Quantity* | *Unit* | *Symbol* | *Definition* |
|---|---|---|---|
| Force | newton | N | 1 N = 1 kg.m/s$^2$ |
| Energy | joule | J | 1 J = 1 N.m |
| Power | watt | W | 1 W = 1 J/s |
| Flux | weber | Wb | 1 Wb = 1 V.s |
| Flux density | tesla | T | 1 T = 1 Wb/m$^2$ |
| Frequency | hertz | Hz | 1 Hz = 1 c/s (s$^{-1}$) |
| Electric conductance | siemens | S | 1 S = 1 A/V |
| Electromotive force | volt | V | 1 V = 1 W/A |
| Pressure, stress | pascal | Pa | 1 Pa = 1 N/m$^2$ |